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DEVELOPMENT OF FENESTRATION IN RUSSIA: STATUS AND PROSPECTS

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The development of fenestration in Russia from 1991 to present is analyzed. A procedure for evaluating the payback of energy-efficient windows in different regions of the Russian Federation is presented. A ranking of territories in the country by new, enhanced values of the heat-transfer resistance of fenestration is proposed.

Key words: fenestration, energy-efficient windows, heat-transfer resistance, payback of energy-saving buildings, ranking of RF territories by use of energy-efficient windows.

It is well-known that modern fenestration is 70 – 80% glass. For example, a 1 m^2 triple-glaze window contains at least 2 m^2 of sheet glass.

The main task of fenestration is to provide standardized natural lighting and a comfortable microclimate in rooms. It is well known [1 – 3] that workers in the windowless commercial buildings built in the 1940 – 1950s in Russia and other countries (mainly the USA) suffered from many psychological and physiological problems and labor productivity was much lower than in similar factories with natural light.

A large number of mainly paired-casement (OS), separated casement (OR) and separated-paired (ORC) wooden windows were manufactured in the USSR. Starting in the 1960s more than 2×10^9 m^2 of such windows have been installed [4]. Numerous inspections performed in recent years have established that the wooden windows fabricated back in the 1930s for 'Stalinist' homes are still fully serviceable and can be refurbished, while mass-produced 'Finnish' windows from that era are practically unrefurbishable — the wood was poorly prepared and is now rotted.

Several factories pressing aluminum profiles were also started up in the 1970s – 1980s. However, aluminum was used mostly for façades, so that energy efficiency is a meaningless concept for them. The first factory manufacturing multiple-pane windows was also started up at that time, but before the 1990s such windows were not used in our country.

The status of window and façade manufacturing by the end of 1991 can be briefly characterized as follows:

– many wooden windows with the old design, not meeting present-day requirements, were produced and even the regulatory documents indicated air intrusion into rooms through the windows;

– aluminum facades (no thermal bridges) were widely used in public and (in part) commercial buildings;

– the first modern fenestration (mostly with PVC profiles) appeared in our country at the end of the 1980s and were unjustifiably expensive;

– by the end of the 1980s the construction industry and therefore the production of fenestration practically collapsed compared with its prime years (end of the 1970s – beginning of the 1980s).

The window materials used by the end of 1991 are shown in Fig. 1*a*.

The market for modern windows in Russia began in the mid-1990s. By 1997 German suppliers of extruded PVC profiles dominated the Russia market (their fraction of all profiles used in Russia was estimated to exceed 80%). The German fraction of the total sales of furniture and accessories was even greater and reached 90%.

Finally, demand for high-quality aluminum appeared — before 1995 'warm' aluminum profiles were mostly imports. Domestic producers appeared later.

A system of domestic standards for window evaluation and use largely based on European analogs started to be developed.

By the end of the 1998 there were more than 2500 firms (mainly small firms) producing windows in Russia.

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Perhaps the most successful period in the development of the mass window market in our country is the period from the beginning to the middle of the 'zero' years. In 2006 the production of windows grew by 40 – 50% (according to different estimates). Mass replacement of old windows in apartment buildings occurred and there was a real boom in the construction of malls and office parks. The increase in the volume of construction and growth in demand stimulated the development of new and further growth of manufacturing capacities and the assimilation of new types of manufacturing (window sills, finishing panels for window casings and others). Domestic producers of PVC profiles started to compete successfully with European trendsetters.

Practically all accessories started to be produced in the Russian Federation. By the end of this stage there were more than 8000 enterprises in the window market. Specialization appeared — many enterprises producing only multiple-glaze windows appeared and many automatic production lines for manufacturing PVC profiles were purchased. Enterprises capable of producing 50,000 – 70,000 m^2 structures per month appeared. In 2007 – 2008 domestic companies set a record in purchases of modern production equipment abroad in expectation of continued phenomenal market growth (based on 2006 results).

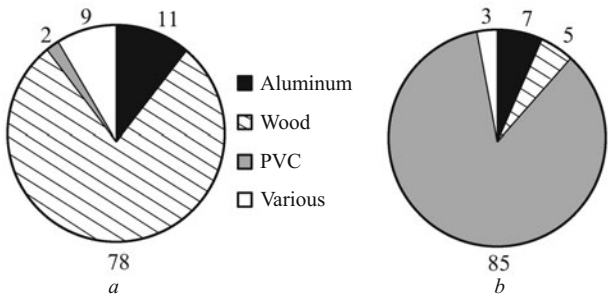
The implementation of a program of complex renovation of apartment buildings with heated walls and replacement of windows and some engineering systems started in this same period. True, the results of this program are unclear. However, it made the development of window companies possible.

The formation of a regulatory framework was completed at the start of the 'zero' years. At the beginning of this decade it started to slip into obsolescence, and because of the financial crisis and the disbanding of State Building Committee of the Russian Federation in 2003 it was not revisited.

During the crisis in 2008 many state and municipal programs, specifically, the program of major renovation of apartment buildings and the federal program 'Affordable and Comfortable Housing', were actually frozen. At the same time the means for social needs appeared; money was provided for upgrading windows. However, the provisions of the Federal Law No. 94 concerning government purchases result in a reduction of window quality because the main criterion for winning a bid for window orders financed through the budget is actually the price exclusively. Any hopes to improve the quality of windows are tied to the introduction of the federal contract system for purchases earmarked for 2014.

However, the production volume of aluminum windows and facades decreased significantly (except in some large cities with the means to construct tall buildings and, of course, Sochi). This market is not expected to recover until 2015 – 2016 at the earliest.

The window market is undergoing some consolidation in connection with the growth of window companies. At the present time the number of companies in the industry has decreased to 5500 – 6000. More small firms are expected to close. The number of window companies is expected to decrease to 4500 by 2016. At the same time many small firms which exist for only one season and produce substandard product are appearing. This situation is due to the cancellation of mandatory certification of windows.



a *b*

Fig. 1. Structure of materials usage for windows, %: *a*) 1991; *b*) 2011.

The Federal Law No. 261 concerning energy conservation was adopted at the end of 2009. However, so far the demand for energy-efficient windows has not increased much.

The process of re-examining the standards associated with the window and façade industry has started. In addition, this is happening mainly not because of government financing but because of orders by professional Associations, specifically, the National Association of Builders.

The situation can be summarized as follows:

– over the twenty year period 1991 – 2011 a modern industry of designing, manufacturing and assembling windows was created in Russia practically from scratch; in terms of production volume this is the third largest such industry in the world (after China and the USA);

– Russian window companies are capable of producing windows of virtually any complexity; the equipment to do this is available in the country; unfortunately, at present, on average the window production capacity does not exceed 55%;

– during the 20 year period of growth the Russian window market when through had peaks (2004 – 2007) and troughs (1999, 2010 – 2011); however, in 2011 – 2013 the mark is stagnating and this condition will probably continue into 2015; market growth, if it even exists (some experts are talking about 3 – 5%), is quite symbolic;

– in Russia the system of regulatory documents, which was created in 1998 – 2003, is quite well developed; but, it needs to be actualized as quickly as possible; this work was activated recently (in 2010 – 2013), including with the participation of professional association of builders and glazers;

– even though the Federal Law No. 261-FZ 'On energy conservation and increasing energy efficiency...' was adopted in 2009, consumers (including government) are not prepared for the fact that the new window designs meeting the requirements of this law will be somewhat more expensive; most

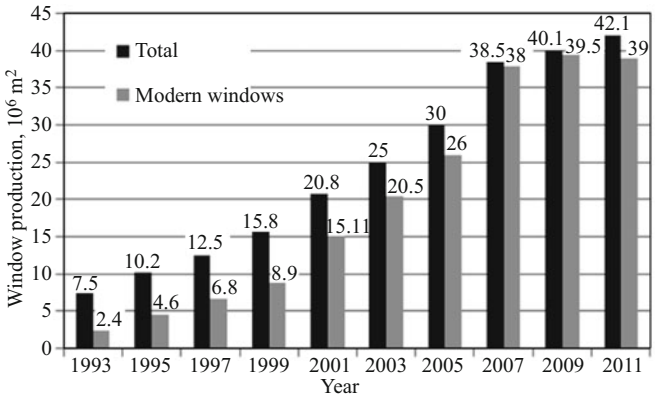


Fig. 2. Window production in the Russian Federation.

large window companies are prepared to produce windows with much better heat-protective properties;

– the structure of the window market has changed considerably (Fig. 1*b*).

A diagram of window production in Russia (Fig. 2) shows consistent constant growth from 1991 to 2008. This is due to the fact that modern windows are installed not only in new but also existing buildings. Moreover, in many window companies the volume of private orders reached 70 – 90% in the middle and end of the zero years. Market growth practically stopped after the crisis in 2008, and it even dropped somewhat in 2010 – 2011. It is obvious that the production of old-style windows is decreasing. However, they are still being produced — for dachas and as replacements (mainly in remote regions). Today the production volume of such windows does not exceed 5 – 7% of the total production of windows. It appears that such windows will be on the market in the future — they have their own consumers.

In the glass industry the per capita glass production is considered to be an indication of the level of development of the country. The same is true for the window industry. This information uniquely characterizes the status of the construction industry as well as the well-being of the citizens (especially in our country where private citizens buy more than half the windows).

Data on window production in some countries and regions in Russia are presented in Tables 1 and 2 [5]. They are quite instructive and very interesting.

We can make the following comments on these tables:

– the window market and per capita window production in Russia correspond to the global level; in the last few years market growth has slowed, and some estimates show it dropping a bit in 2010 – 2011;

– the American window market have been quite stable for many years now;

– window production in China grew rapidly to 2010 and then it slowed down somewhat in connection with the completion of construction for the Olympics in Beijing in 2008 and Expo in Shanghai in 2010;

TABLE 1. Per Capita Window Production in a Number of Countries (m^2/yr) in 2004 and 2010

Country	2004	2010
USA	0.35	0.37
Germany	0.27	0.30
China	0.15	0.34
Russia	0.16	0.29

TABLE 2. Per Capita Window Production in Some Regions of the Russian Federation (m^2/yr) in 2004 and 2010

Region	2004	2010
Moscow	0.32	0.38
Moscow Oblast'	0.25	0.43
St. Petersburg	0.19	0.35
Rostov	0.21	0.29
Khanty-Mansiisk	0.41	0.24
Samara	0.22	0.28
Ekaterinburg	0.21	0.34
Novosibirsk	0.20	0.30
Vladivostok	0.05	0.16

– the regional growth of the window market in Russia is gradually leveling; however, once again, it is underdeveloped in the eastern regions of the country compared with the central regions.

The main reasons that modern energy-conserving windows are not used in Russia are well known [6, 7]. According to the authors there are three reasons:

– window companies are some of the last subcontractors arriving at a site and have practically no possibility of influencing the design process and proposing their variants of a solution for glazing the building that would provide better (though more expensive) heat-engineering performance;

– in the current regulatory documents as well as in subordinate acts to the Federal Law No. 261-FZ adopted on November 29, 2009 "On energy conservation and increasing energy efficiency...", just as in the decisions of federal (and regional) agencies responsible for energy conservation in construction, there is no strict 'compulsion for energy conservation';

– once again the main 'technical characteristic' of any building structure for the final user is the price; it is necessary to take account of the fact that when buying modern energy-saving (but somewhat more expensive) windows, aside from reducing the cost of heating energy-saving windows can increase room comfort and allow better room usage because the temperature of the interior glass is higher.

In mid-2012 we conducted a special investigation to determine how much more expensive modern energy-saving windows are compared with the ones installed in 95% of

Russian buildings. The leading window producers in Moscow, Ryazan', Irkutsk and Khabarovsk were asked to consider an order for fabricating and installing 1000 windows with different configurations in three variants:

1) quadruple-glaze (three-space) PVC profile with a 4-12-4-12-4 double-glaze (two-space) packet with M1 glass (the variant most commonly used and sold today with reduced heat-transfer resistance $R \approx 0.54 – 0.58$ m$^2 \cdot$ K/W);

2) five-space PVC profile with an I4-12Ar-4-12Ar-4 two-space packet with a soft heat-reflecting low-emission coating on one pane and argon-filled interpane space (a more efficient glazing variant compared with the preceding one, $R \approx 0.67 – 0{,}72$ m$^2 \cdot$ K/W);

3) five-space PVC profile with an I4-12Ar-4-12Ar-I4 tow-space packet with soft heat-reflecting low-emission coating on two panes and argon-filled interpane space (more efficient glazing variant than the preceding ones, $R \approx 0.87 – 0.98$ m$^2 \cdot$ K/W).

Any large company can be fabricated all window variants without additional equipment.

Detailed information on the research performed together with an analysis of the change in the cost of windows in the period 2007 – 2012, the window fraction of living costs in different regions, the cost of turn-key assembly (including the cost of sills, casing finishing panels, stools, and so on) in the cities chosen is presented in [5].

The main conclusion drawn from this work was that energy-saving windows (variant 3) are not much more expensive than the most commonly installed and inefficient windows (variant 1). It is obvious that the cost of energy-efficient windows will rapidly decrease as demand increases.

We shall not present all information about the studies performed. For example, the cost of windows with different heat-engineering characteristics is presented in Table 3 (the data were provided by one of the larger manufacturers in Moscow).

Even similar, very profitable products offered in the Russian window market by well-known window companies are not in great demand because they run up against the same barrier — the Federal Law No. 94-FZ.

In our opinion consumers and builders are unjustifiably rejecting good energy-saving windows. These windows cost practically the same amount as the ordinary ones and offer significant benefits.

On the basis of the data presented in [5] the payback of energy-efficient windows was determined and recommendations were made for increasing the standard R values of the windows in different regions of Russia [8].

In the present article we shall examine only the computational results for the simple payback based on the data in Table 3. This information for regions, including an estimate of the net present value, obtained using simplified formulas according to the method of [9], is presented in [8].

A wide range of questions must be taken into account in order to estimate the efficiency of energy saving measures in construction: natural lighting, heating, ventilation and many other factors affecting room comfort. For this reason the estimated payback of only energy-efficient fenestration compared with the most widely used inexpensive articles is quite conditional, but it gives a complete idea about how rapidly additional investments made in precisely this component of a building are paid back.

TABLE 3. Comparative Technical Characteristics and Cost of OR 15-15 Window Units According to Date Provided by PIK PROFIL' (January 2012)

Structural composition	Glass packet formula	R, m$^2 \cdot$ K/W	Cost, rubles	
			1 m^2	windows
Frame (127/70), casement (77/70), energy-saving glass packet	4-14-I4-14-I4	0.95	5119	10,904
Frame (127/70), casement (77/70), energy-saving glass packet	4-20-I4	0.69	4713	10,038
Frame (63/70), casement (77/70), energy-saving glass packet	4-14-I4-14-I4	0.75	4664	9934

Energy-efficient windows pay for themselves and a profit from their installation is possible in all cases where the operation of the heating and ventilation system is correctly controlled and the payment for heat is based on meter indications. Heat meters are installed in the overwhelming majority of modern buildings, just as in office buildings, individual residences and many industrial enterprises.

Energy-efficient windows will pay for themselves more quickly in buildings equipped with centralized or individual ventilation and air conditioning systems (this situation is not taken into account in this article) because electricity on cooling is saved during the summer.

The return on *additional* investments in increasing the energy efficiency of windows compared with the windows most commonly used in a particular region was estimated.

To create a comfortable microclimate in rooms with modern sealed windows it is necessary to provide standard ventilation. One of the most commonly used methods of standard ventilation in rooms which are not equipped with convection-exhaust ventilation systems is the use of special equipment to air out rooms (window/wall air inlets) but even then it is still necessary to install a system to remove stale air. The increase in the cost of windows due to the cost of airing out a room was not examined in our calculations of the payback — the installation of new sealed fenestration must always include the installation of convective ventilation.

The main factors determining the heat losses through a window are its heat-protective properties and the difference between the average temperature inside and outside a room.

TABLE 4. Example of a Calculation of the Simple Payback for Moscow (Cost of Construction from Table 3 for Materials from the PIK PROFIL' Company)

Index	Glazing variant	
	1	2
Heat transfer resistance R, $m^2 \cdot K/W$	0.69	0.95
Total cost, rubles/m^2	4713	5119
Additional investments, rubles/m^2	–	406
DDHS in chosen region	4600	
Heat losses, $kW \cdot h/(m^2/yr)$	160	116
Energy savings, $kW \cdot h/(m^2/yr)$	–	44
Thermal energy prices, rubles/Gcal	1558	
Cost of 1 $kW \cdot h$ of heat, rubles/$(kW \cdot h)$	1.33	
Cost of energy saved, rubles/m^2	–	58.5
Simple payback time, yr	–	6.9

The total heat losses depend on the glazing area and building size, but in calculations it is convenient to use specific values. The heat losses through a 1 m^2 window during the heating season Q_{hs} ($kW \cdot h/m^2$) can be calculated using the relation

$$Q_{hs} = \text{DDHS} \times 0.024/R,$$

where DDHS represents the degree-days of the heating season in the region of interest and R is the reduced heat-transfer resistance of the window, $m^2 \cdot K/W$. The coefficient 0.024 is the conversion factor from watts (W) to kilowatts (kW) as well as days into hours.

For Moscow DDHS is 4600. The reduction in heat losses through a 1 m^2 window in one heating season as result of an increase in the reduced heat-transfer resistance of the structure according to Table 3 by 0.26 $m^2 \cdot K/W$ is 44 $kW \cdot h/m^2$ for Moscow.

Thermal energy prices also have a large effect on the payback of construction (aside from the difference in the cost of different window variants). The price during the second half of 2013 in Moscow was used for the calculations — 1558 rubles/Gcal (http://www.oaomoek.ru/content/view/414/119/).

The computational results for the simple payback of energy-saving windows (glazing variant 2) compared with the most commonly used windows (glazing variant 1) are presented in Table 4.

The simple payback period is the additional investment required to install an energy-efficient window divided by the yearly heat savings. Of course, the total cost must include services, accessories and so forth. The cost and savings for different types of windows for their entire service life, which can exceed 30 yr, must be taken into account.

In summary, the increase in the cost of energy-efficient windows (see Table 3) over the conventional windows is recouped in less than 7 yr due to the reduction of heat losses from rooms through the fenestration. The simple payback period depends on the increase in the cost of windows and the climatic conditions as well as on the regional heat prices. For the extant upward trend of heat-carrier prices the simple payback for energy-efficient structures will decrease.

The climatic conditions play the decisive role in choosing the energy characteristics of windows. In cold regions it is important to have good thermal insulation, and in order to lower the heat consumption of a building the windows must transmit sunlight. In warm regions the thermal insulation properties can be somewhat lower but the window glazing must possess sun-screening properties, which will make it possible to lower the cost of cooling buildings during the summer. Although the minimum requirements for the heat-protective characteristics of windows taking accounting of the climatic conditions exist in Russia these requirements were set at a quite low level, especially for the southern and central regions.

The calculations show that the *additional* investment in fenestration with enhanced heat-engineering characteristics is recouped quite quickly. This allows us to recommend that consumers use windows with higher heat-engineering characteristics than those proposed by the operative regulatory documents. On the basis of our experience and calculations we recommend windows with higher heat-transfer resistance (Table 5).

The energy savings from using different fenestration can be quickly estimated from Table 6. The characteristics of fenestration recommended for different regions depending

TABLE 5. Obligatory and Recommended Values of the Reduced Heat-Transfer Resistance Depending on the Climatic Region of the Construction Site

Parameter	Obligatory minimum requirements					
DDHS	2000	4000	6000	8000	10,000	12,000
R, $m^2 \cdot K/W$	0.3	0.45	0.6	0.7	0.75	0.8
	Recommended values					
DDHS	To 4000		4000 – 6000	6000 – 8000	8000 or more	
R, $m^2 \cdot K/W$	0.60		0.75	0.80	0.90	
Climatic zone for use of fenestration [8]	1		2	3	4	

TABLE 6. Heat Losses through Windows, kW · h/(m²/yr), in Different Climates

	R, m² · K/W	Degree-Days of the Heating Period									
		1000	2000	3000	4000	5000	6000	7000	8000	10,000	12,000
Recommended values	**0.30**	80	160	Forbidden							
	0.35	69	137								
	0.40	60	120	180							
	0.45	53	107	160	213						
	0.50	48	96	144	192						
	0.55	44	87	131	175	218					
	0.60	40	80	120	160	200	240				
	0.65	37	74	111	148	185	222	258			
	0.70	34	69	103	137	171	206	240	274		
	0.75	32	64	96	128	160	192	224	256	320	
	0.80	30	60	90	120	150	180	210	240	300	360
	0.85	28	56	85	113	141	169	198	226	282	339
	0.90	27	53	80	107	133	160	187	213	267	320
	0.95	25	51	76	101	126	152	177	202	253	303
	1.00	24	48	72	96	120	144	168	192	240	288

on the DDHS are indicated in the table and the range of values forbidden by the operative building regulations 'Heat screening of buildings' is also given.

The Russian window market has developed quite successfully in recent years [4]. Large companies are ready to produce fenestration of practically any complexity. Today even a medium-size company can produce energy-saving windows with a very small cost increase. The low production volume of energy-efficient fenestration is explained by inadequate consumer demand, which is due to, among other things, confusion about the impossibility of recouping the added investment.

One would very much like to believe that in Russia not only the attitude toward energy-saving windows will change in the next few years but new technological advances in increasing the energy efficiency of fenestration will also be in demand.

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